UNIVERSITAT POLITÈCNICA DE CATALUNYA
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Bachelor's Degree in Aerospace Technology Engineering

Bachelor Thesis

Project of designing and manufacturing a small horizontal axis wind turbine using 3D printing technologies

Document: **TECHNICAL SHEETS**

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Delivery date: 27/04/2020

Presentation date: 11-22/05/2020

Contents

List of Figures

List of Tables

Chapter 1

Wind turbine main characteristics

In this document the main characteristics of the wind turbine designed will be described.

Table 1: General turbine data.

Design power	63 W
Rated power	300 W
Design rotor speed	384 rpm
Rated rotor speed	650 rpm
Cut-in wind speed	4.2 m/s
Rated wind speed	8.4 m/s
Design wind speed	13 m/s
Reference wind speed (50 years return)	42 m/s
Number of blades	3
Rotor diameter	1 m
Architecture	Horizontal axis
Power control	Passive
Gear ratio	1 (Direct drive)
Rotor position	Upwind
Rotational sense of motion (viewed from upwind)	Clockwise
Generator type	Three phase permanent magnet
Generator magnets material	NdFeB
Loads wind class	IEC 61400-2 Class IV
Blades airfoil	S1223
Starting torque	0.28 Nm
Blades shell material	3D printed PETG
Blades beam material	Carbon fiber
Blades inserts material	Aluminum
Shaft material	Cast iron
Tower material	Steel

The mass and data inertia of each component is summarized in the following table:

Table 2: Mass and inertia data.

Tower top mass	9.2 kg
Tower mass	25.8 kg
Blade tip part mass	0.149 kg
Blade root part mass	0.156 kg
Pin joints mass	0.022 kg
Beam mass	0.023 kg
Total blade mass	0.350 kg
Hub mass	0.355 kg
Generator mass	4.3 kg
Generator inertia	0.040 kgm^2
Blades inertia	0.177 kgm^2
Yaw axis inertia	0.781 kgm^2

Finally, the main geometrical dimensions are presented in the next table:

Table 3: Geometrical data.

Rotor diameter	1 m
Hub radius	0.1 m
Tower height	6 m
Tower exterior diameter	60 mm
Tower interior diameter	54 mm
Blade center of gravity - rotor axis distance	270 mm
Rotor center - first bearing distance	150 mm
Rotor center - yaw axis distance	300 mm
Tail center of pressure - yax axis distance	600 mm
Tail surface	65000 mm^2
Nacelle length	300 mm
Nacelle diameter	150 mm
Blade beam exterior diameter	15 mm
Blade beam interior diameter	12 mm
Generator shaft diameter	22 mm

Chapter 2

Rotor manufacturing process

The rotor manufacturing process will be described in this chapter.

2.1 Blades

Firstly, the two parts of the blade must be 3D printed according to the settings defined in the Section 6.5 of the Report.

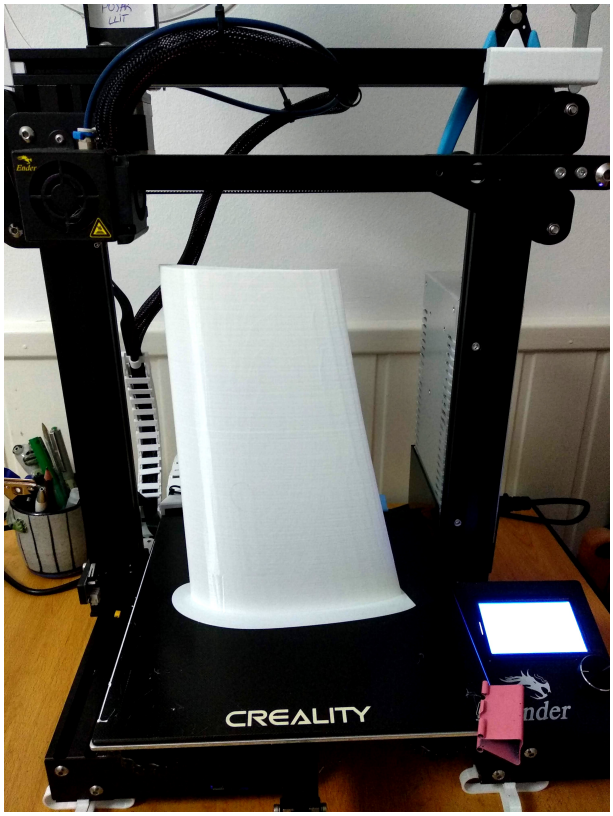
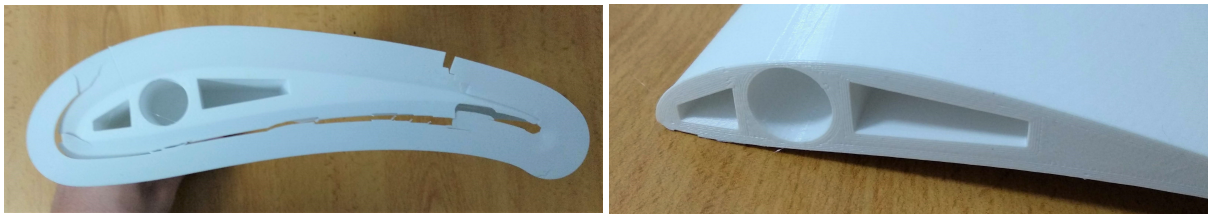


Figure 1: Tip part of the blade freshly printed.

The brim used to improve the bed adhesion must now be removed. It should be done carefully, and the use of the angle-cutter that is provided with the Ender 3 printer really simplifies the process. Ideally, no small rests of layers shall surpass the blade boundaries, because they would

create imperfections and lumps in the blade joint.



(a) Brim layer. (b) Blade middle section prepared.

Figure 2: Blade "bed" section before and after brim removal.

Apart from removing the supports, it is important to take out all the stringing resultant of the printing process, which specially appears near the trailing edge.

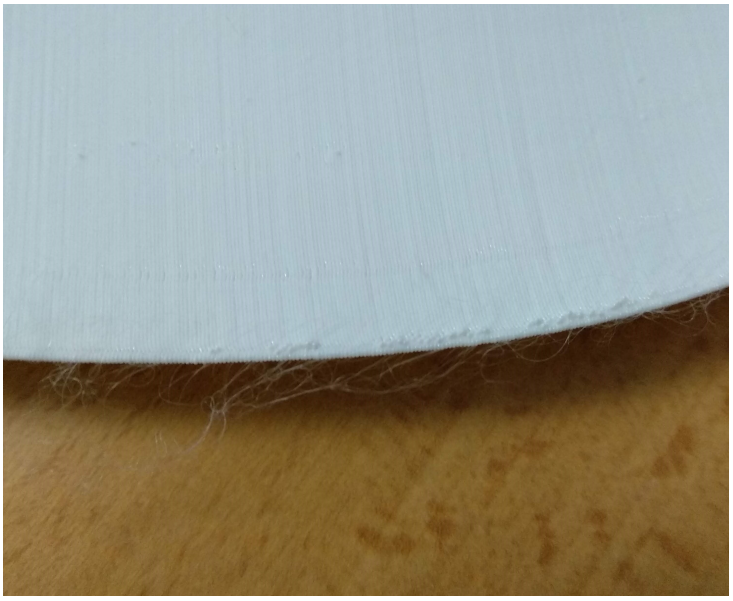


Figure 3: Stringing produced in the blade.

It may also appear inside the beam hole, as shown in the following figure. It can removed by pulling in and out the beam and dragging them away.

Figure 4: Stringing produced inside the beam hole.

The same process should be conducted for the other part of the blade. Once both parts are ready, they should be joint by means of the pin joints, which should be glued together using Araldite Standard. The small gap resultant of the joint must be covered using insulating tape as shown in the following figure:

Figure 5: Blade joint covered with insulating tape.

Once both parts are joined together, the whole blade must be painted to provide a smoother surface finish and ensure protection against the UV radiation. Firstly, a plastic primer should be applied. Two thin layers spaced one hour are used. Then, an spray withe matte is applied. This is only to provide even more adhesion to the main coating: an enamel white matte paint.

Figure 6: Applying the layer of spray paint.

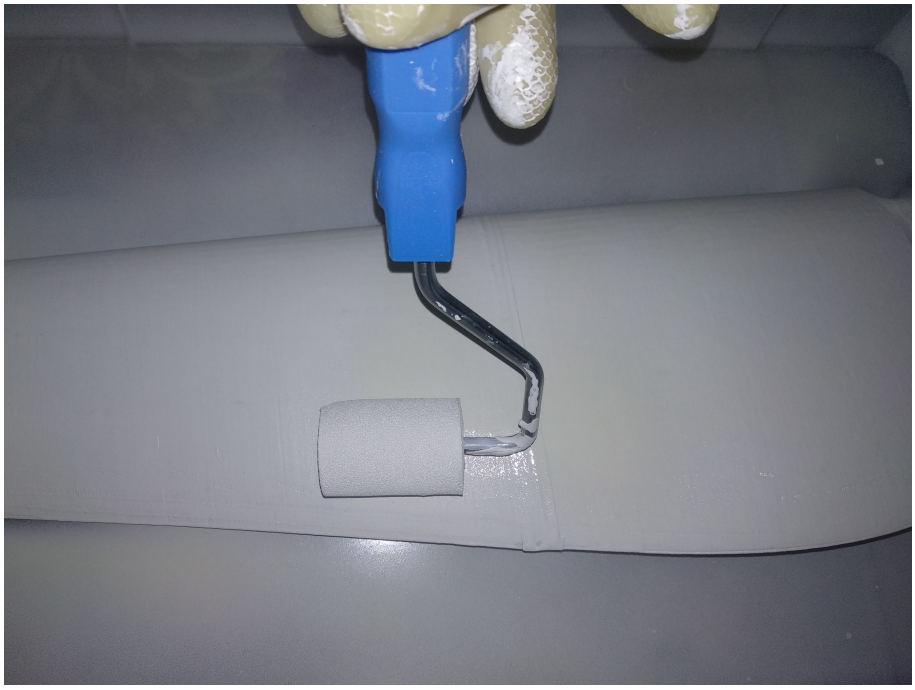


Figure 7: Painting the blade with enamel.

2.2 Hub

The first requirement to manufacture the hub is to recollect patience for the +28h print. It is also important to keep it monitored and minimize the time that the printer is working without supervision. Any malfunction could lead to the whole printer to broke, and it can even be a fire hazard.

Figure 8: Ongoing printing of the hub (10 h).

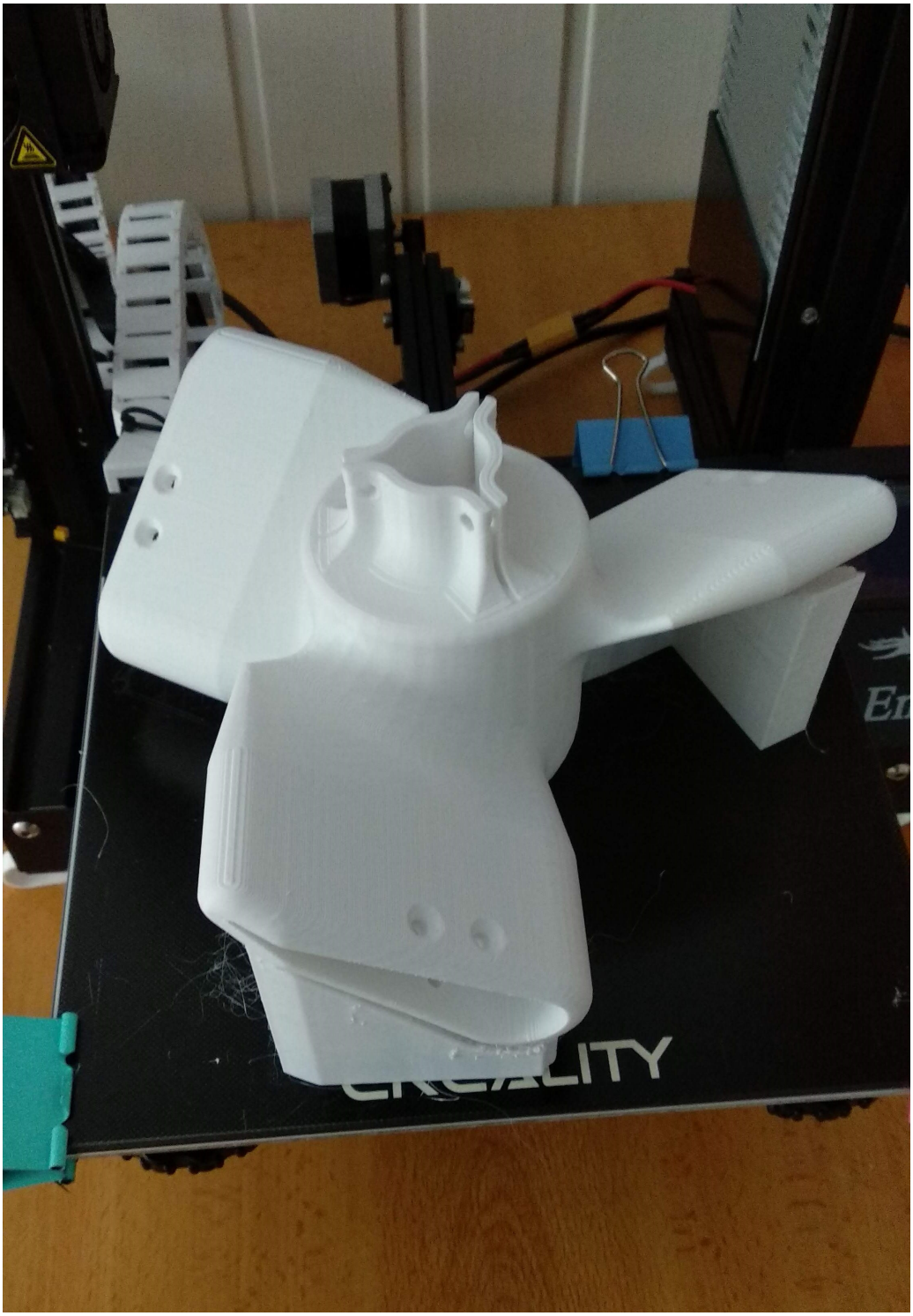


Figure 9: Hub print finished.

Given the shape of the hub, the supports are unfortunately required, so the following step is to carefully remove them as shown in the following pictures.

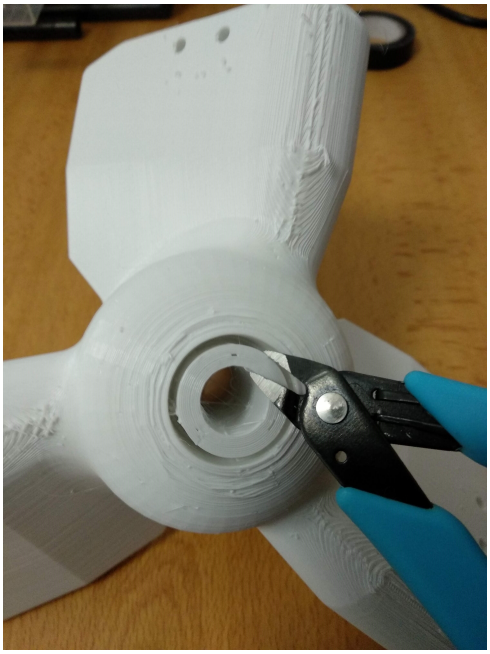


Figure 10: Hub support removal process.

Figure 11: Hub without the support material.

The next step is painting the part using the same process that was followed for the blades. Special attention must be applied in the areas where the supports held the hub, because the surface finish is very irregular and the paint may help to homogenize it. Once they are printed and dry, the inserts for the blade beam should be screwed in using an Allen key.

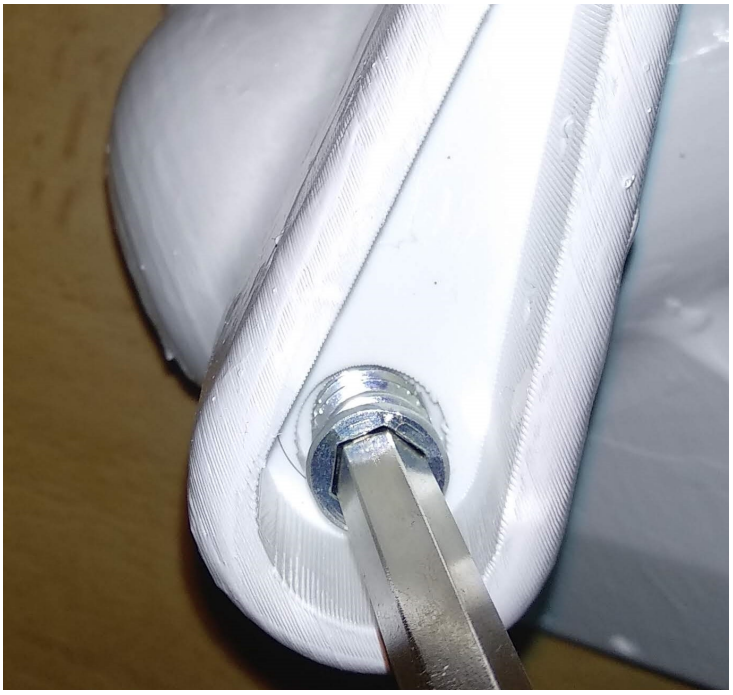


Figure 12: Screwing the insert with an Allen key.

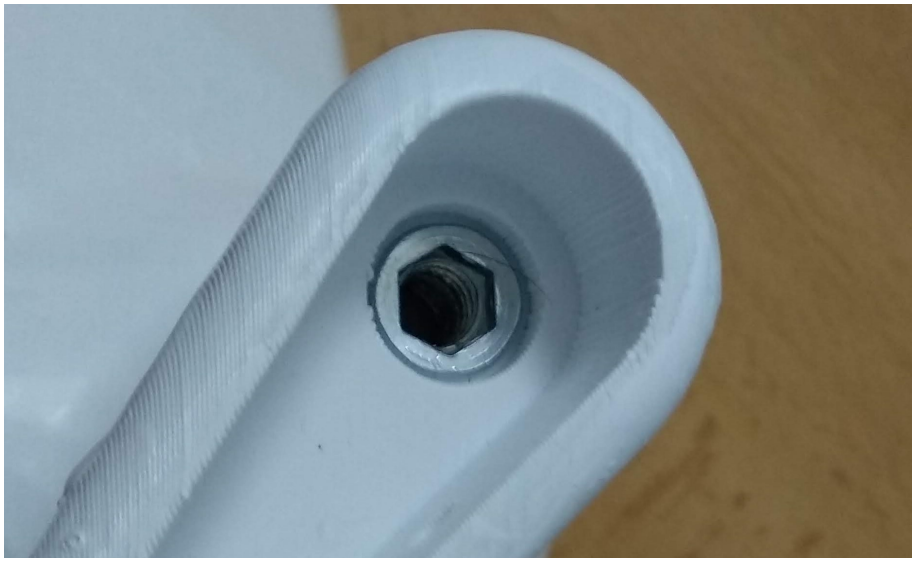


Figure 13: Blade insert inside the hub.

The same procedure should be followed with the inserts for the main shaft.

2.3 Blade-Hub joint

The most critical part is the bonding between the beam and the insert, because the load will be maximum there and the surface of contact is very reduced. Hence, it is important to ensure a great joint. Firstly, the surface of both the insert and the beam must be sanded. A sanding paper with 400 grit size has been used.

Figure 14: Sanding process of the beam interior.

The carbon fiber particles that pop off are a health hazard, so it is required to do this process in a well ventilated area while wearing a respirator.

Figure 15: Carbon fiber particles after the sanding process.

Once the sanding is completed, the surface must be cleaned with alcohol to remove any possible rest of material or grease.

Figure 16: Cleaning the beam interior.

Once the surface preparation is ready, two equal parts of Araldite Standard should be mixed together during 2/3 minutes. Then, the mixed epoxy should be evenly applied in the insert and the beam, ensuring an equal layer without any bubble. The use of a brush is required for this step.

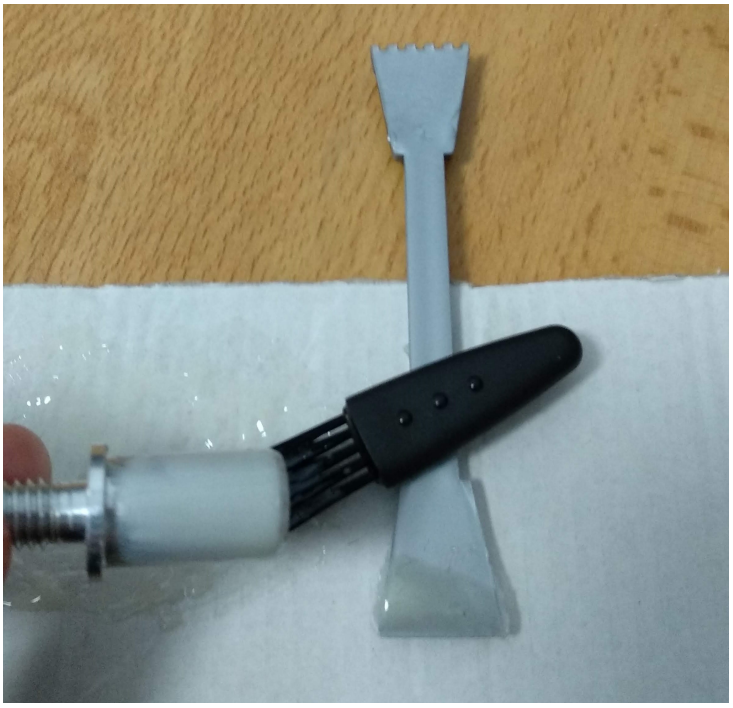


Figure 17: Glue applied on the insert.

Finally, both pieces must be bonded together. It is important to introduce the insert in the axial direction without any twisting, because it would add bubbles and areas without glue. Once they are well fitted together, the extra glue on the outer part must be removed.

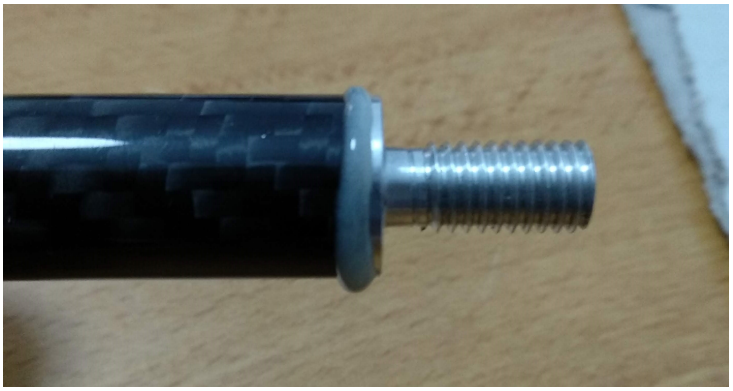


Figure 18: Beam-insert fitted before removing the extra glue.

The bond must cure for more than a day in a position that does not add extra stresses. Once it is completed, it can be screwed into the hub insert as follows:

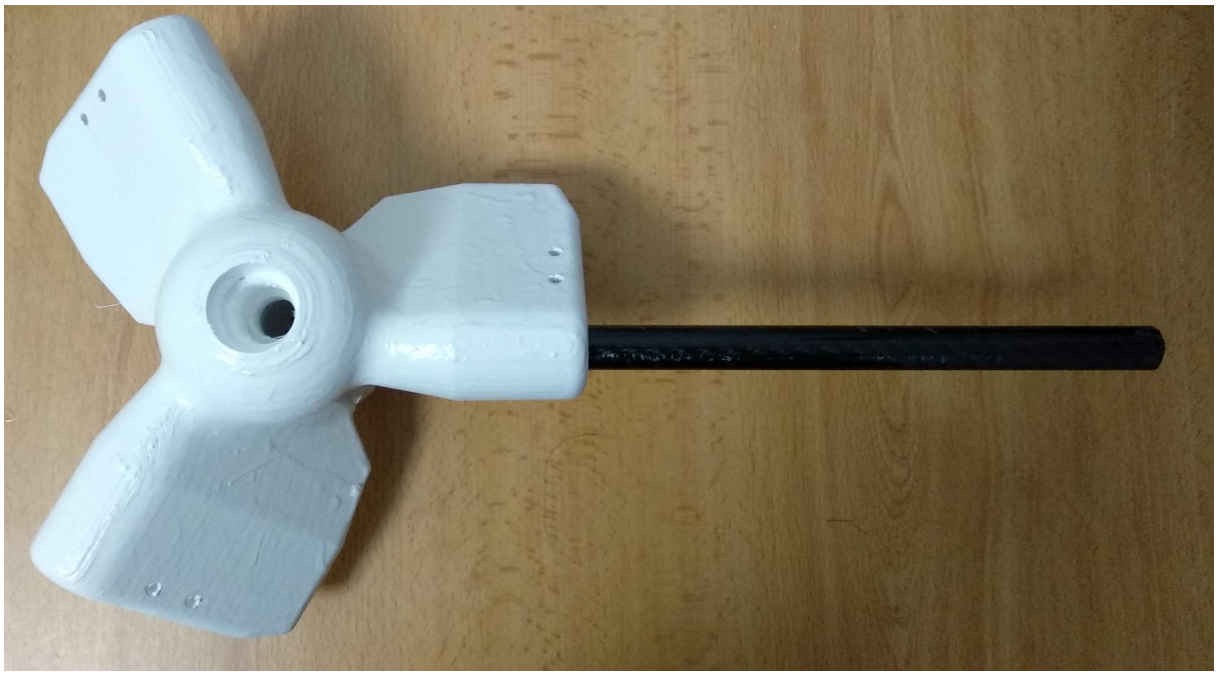


Figure 19: Blade beam screwed into the insert.

Once the beam is secured inside the hub, the blade must be inserted in the beam. Before that, all the beam must be covered in Araldite Standard to ensure a good bonding.

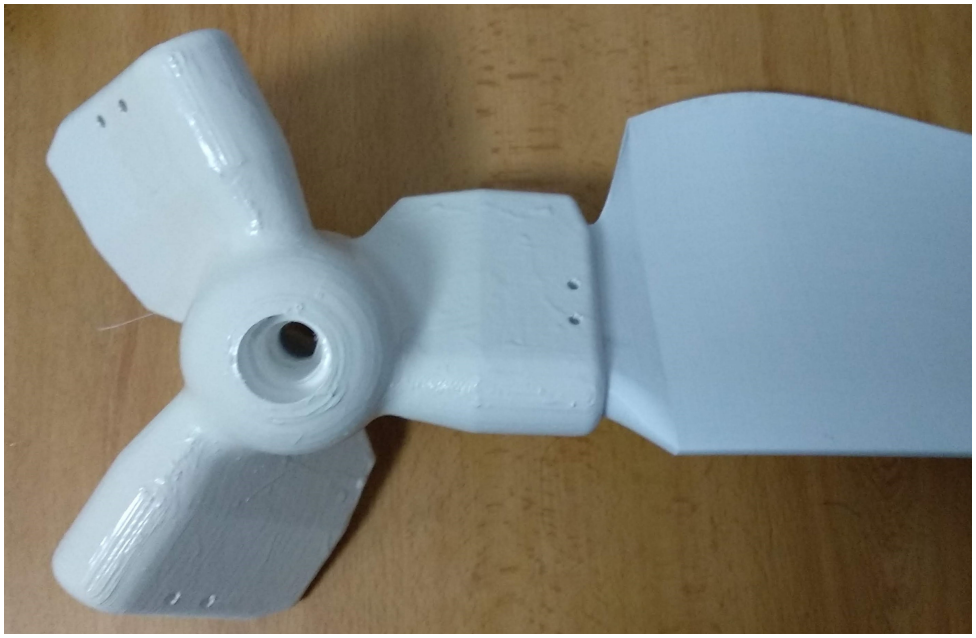


Figure 20: Blade inserted into the beam.

The last step to avoid tolerances and ensure a good fit with the hub is to use 2 M4 screws to fix the blade:

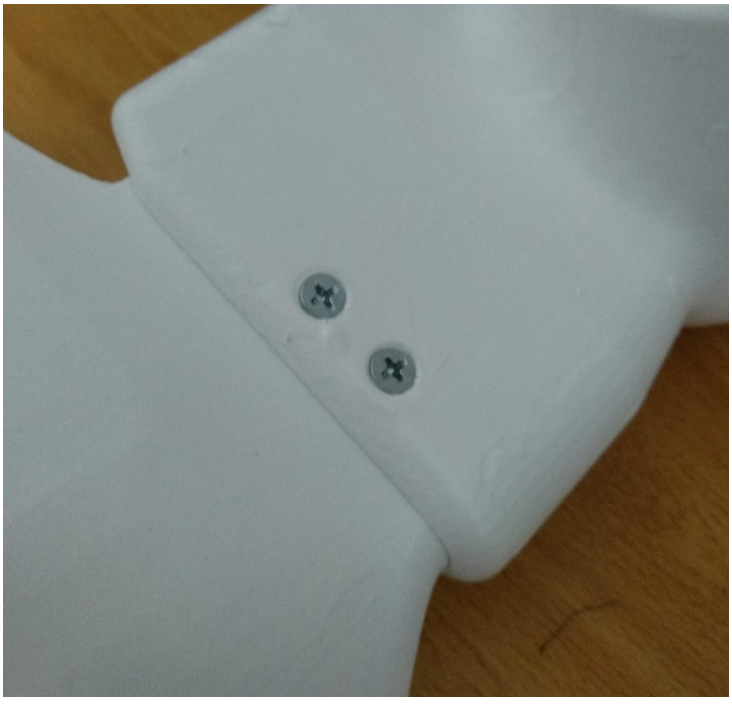


Figure 21: M4 screws to secure the joint.

Repeating this process for the other blades, the rotor is finally assembled:

Figure 22: Rotor manufactured and assembled.